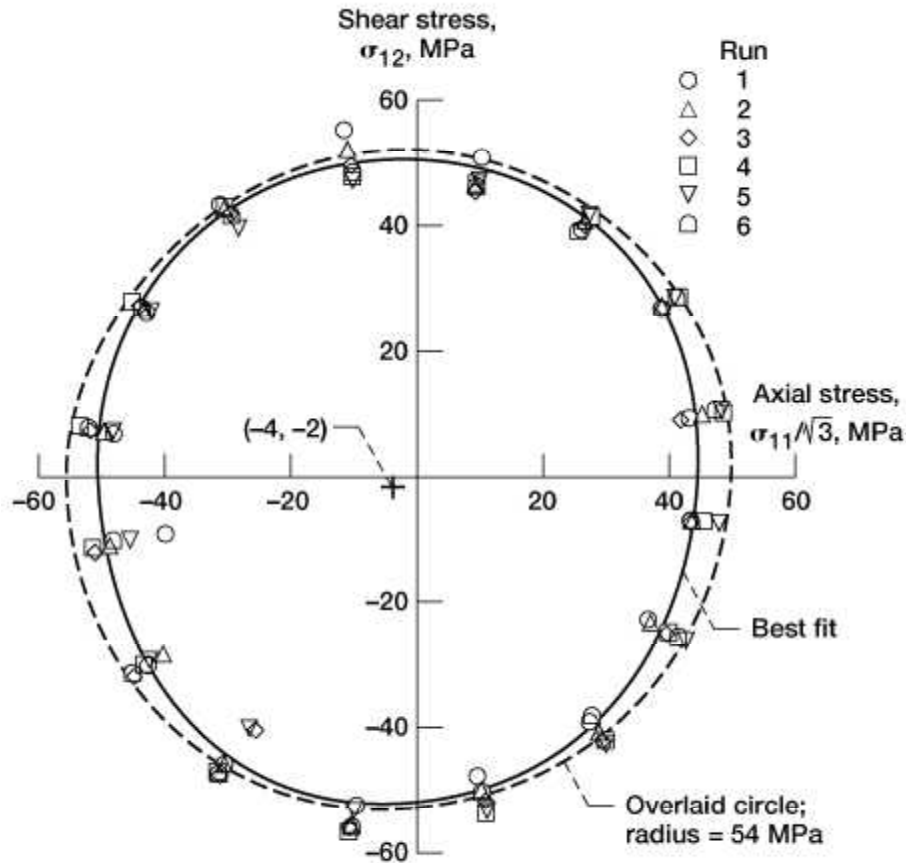


# Experimental Techniques Verified for Determining Yield and Flow Surfaces

Structural components in aircraft engines are subjected to multiaxial loads when in service. For such components, life prediction methodologies are dependent on the accuracy of the constitutive models that determine the elastic and inelastic portions of a loading cycle. A threshold surface (such as a yield surface) is customarily used to differentiate between reversible and irreversible flow. For elastoplastic materials, a yield surface can be used to delimit the elastic region in a given stress space. The concept of a yield surface is central to the mathematical formulation of a classical plasticity theory, but at elevated temperatures, material response can be highly time dependent. Thus, viscoplastic theories have been developed to account for this time dependency.

Since the key to many of these theories is experimental validation, the objective of this work (refs. 1 and 2) at the NASA Lewis Research Center was to verify that current laboratory techniques and equipment are sufficient to determine flow surfaces at elevated temperatures. By probing many times in the axial-torsional stress space, we could define the yield and flow surfaces. A small offset definition of yield ( $10\ \mu\epsilon$ ) was used to delineate the boundary between reversible and irreversible behavior so that the material state remained essentially unchanged and multiple probes could be done on the same specimen. The strain was measured with an off-the-shelf multiaxial extensometer that could measure the axial and torsional strains over a wide range of temperatures. The accuracy and resolution of this extensometer was verified by comparing its data with strain gauge data at room temperature. The extensometer was found to have sufficient resolution for these experiments. In addition, the amount of crosstalk (i.e., the accumulation of apparent strain in one direction when strain in the other direction is applied) was found to be negligible.

Tubular specimens were induction heated to determine the flow surfaces at elevated temperatures. The heating system induced a large amount of noise in the data. By reducing thermal fluctuations and using appropriate data averaging schemes, we could render the noise inconsequential. Thus, accurate and reproducible flow surfaces (see the figure) could be obtained.



*Flow surfaces for 316 stainless steel at 650 °C.*

With the experimental equipment verified, it is now possible to validate multiaxial, viscoplastic theories. Future work is planned to examine multiaxial effects in composites and superalloys commonly used in advanced aircraft engines.

## References

1. Lissenden, C.J., et al.: Verification of Experimental Techniques for Flow Surface Determination. NASA TM-107053, 1996.
2. Lissenden, C.J., et al.: Experimental Determination of Yield and Flow Surfaces Under Axial-Torsional Loading. S. Kalluri and P.J. Bonacuse, eds., Am. Soc. Test. Mater. Spec. Tech. Publ. 1280, 1997, pp. 92-112.

**Lewis contacts:** Brad A. Lerch, (216) 433-5522, Bradley.A.Lerch@grc.nasa.gov, and Rod Ellis, (216) 433-3340, John.R.Ellis@grc.nasa.gov

**Authors:** Brad A. Lerch, Rod Ellis, and Cliff J. Lissenden

**Headquarters program office:** OASTT

**Programs/Projects:** Propulsion Systems R&T, HITEMP